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Monitored Natural Recovery Evaluation Report

Yosemite Slough Sediment Site
San Francisco, California

July 2012

ARCADIS

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Monitored Natural Recovery Evaluation Report

Yosemite Slough Sediment Site
San Francisco, California

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Table of Contents

1. Introduction

ARCADIS U.S., Inc. (ARCADIS) has prepared this report to present the results of a monitored natural recovery (MNR) evaluation completed for a multi-technology alternative (herein referred to as Alternative 1) for the Yosemite Slough Sediment Site located in San Francisco, California (the site). This evaluation uses existing site data and the SEDCAM model (Jacobs et al. 1988 and Washington Department of Ecology [Ecology] 1991) to predict sediment concentrations of site contaminants of concern (COCs), including lead, zinc, and total polychlorinated biphenyls (PCBs), at future points in time after implementation of the site-wide remedy. This work was completed to assess the degree to which risk reductions could be achieved at the site within a reasonable time period through the use of MNR in combination with other remedial technologies such as removal and capping. The outcome of the work is remedial Alternative 1 (Figure 1), evaluated in the Engineering Evaluation/Cost Analysis (EE/CA) for the site.

1.1 Monitored Natural Recovery

As described in the USEPA Contaminated Sediment Remediation Guidance (USEPA, 2005), MNR uses ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contamination in sediment. Physical, biological, and chemical mechanisms act together to reduce the risk posed by the contamination, and risk reduction may occur in a number of different ways. Figure 2 provides a conceptual depiction of MNR processes that can contribute to risk reduction over time. Evaluating the success of MNR relies on collection of data during regular monitoring activities, and is a critical component to any remedy that includes MNR.

MNR has been successfully applied at a number of Superfund sites as a component of a multi-technology approach. Recent examples include:

- Onondaga Lake Bottom Subsite, Syracuse, NY (COC: mercury);
- Lake Hartwell Superfund Site Operable Unit 2, Pickens, South Carolina (COCs: PCBs);
- Commencement Bay Nearshore Tideflats, Tacoma, Washington (COCs: metals, PCBs, PAHs);

- Bremerton Naval Complex Operable Unit B, Bremerton, Washington (COCs: PCBs, mercury);

- Lavaca Bay, Point Comfort, Texas (COCs: inorganic mercury, methymercury, and PAHs).

1.2 Modeling Process

The process for modeling the MNR, described in this report, is as follows:

- Calculation of area-weighted average (AWA) concentrations for the site based on layout of Alternative 1 at time zero after remedial implementation (i.e., after caps are installed in areas of the site identified for capping)

- Gathering model inputs for the SEDCAM mixing model

- Performing SEDCAM modeling

- Comparison of SEDCAM results to proposed Removal Action Levels (RALs) to assess whether concentrations can reach acceptable levels within a 5 year timeframe.

The process listed above was undertaken in iterations until the calculated AWA concentrations were reduced to below RALs within 5 years to evaluate the correct balance between capping and MNR areas for Alternative 1. Each of these steps is described in more detail in the following sections.

2. Area-Weighted Average Approach

Consistent with the data evaluation method used at Hunters Point Shipyard, located in San Francisco, California (Barajas and Associates, Inc., 2008), an AWA approach was used to calculate the concentrations of COCs in sediment at time t=0 and time t=5 years after the remedy is implemented (i.e.,after MNR processes have been ongoing) to evaluate the degree to which risk reduction that could be achieved by using MNR at the site. A stepwise process was used for the AWA approach.

First, data from the top 1 foot of sediment (i.e., the biologically active zone [BAZ]) from discrete sample points were screened against the proposed RALs, as shown on Figure 1:

- For PCBs, the not-to-exceed concentration of 1,240 micrograms per kilogram (µg/kg) was used
- For lead, the proposed RAL of 218 milligrams per kilogram (mg/kg) was used
- For zinc, the proposed RAL of 410 mg/kg was used.

Based on the results of the screening, each sample location was selected for a potential remedial category as follows:

- Sample locations where concentrations were less than the proposed RALs/not-to-exceed concentrations were designated “No Action.”
- Sample locations where concentrations were greater than the proposed RALs/not-to-exceed concentrations but less than a factor of 3, were designated “MNR” except for the following locations that were included in the MNR category based on their concentrations and surrounding data points:
    - YC-003 has concentrations exceeding the total PCB RAL by a factor of 3.1 and the lead RAL by a factor of 4.1, but adjacent locations YC-001 and YC-004 are below RALs.
    - YC-012 has concentrations exceeding the lead RAL by a factor of 5.2, but PCBs at the same location are below 3 times the RAL and adjacent locations YC-11 and YC-14 are below RALs.

- YC-026 has concentrations exceeding the lead RAL by a factor of 5.6, but PCBs at the same location are less than 3 times the RALs, location YC-024 is less than 3 times the RALs for lead and below the RAL for PCBs, and surrounding locations YC-023, YC-025 and YC-033 are below the RALs.

- Sample locations where concentrations were greater than the proposed RALs/not-to-exceed concentrations by more than 3 factors (excluding the three locations listed above), were designated "capping."

Next, for the AWA calculation, Thiessen polygons were constructed by geospatially dividing the site based on sample location density and the site boundary. Thiessen polygons are constructed by perpendicularly bisecting the line between a selected point and all adjacent points, so the sides of each polygon are equidistant from adjacent sampling locations. The unsampled area contained within each polygon is nearest to the associated sample and, therefore, the concentration for the entire area contained by the polygon is assumed to be equal to that of the associated sample. A weighting factor is then applied to a sample based on the proportion of surface area within the polygon associated with the sample.

For this evaluation, concentrations of COCs between zero and 1 foot below sediment surface (bss) were used to calculate AWA concentrations. Because the top 1 foot of sediment will be removed prior to capping, and replaced with cap material, COC concentrations applied to Thiessen polygons in remedial units identified for capping were replaced with concentrations representing clean backfill:

- For PCBs, 24.6 µg/kg was used based on the dredged material testing threshold for San Francisco Bay Area sediment for 2012 (San Francisco Estuary Institute [SFEI] 2012).

- For lead, 43.2 mg/kg was used based on the San Francisco Bay Ambient concentrations (San Francisco Regional Water Quality Control Board [RWQCB] 2000).

- For zinc, 158 mg/kg was used based on the San Francisco Bay Ambient concentrations (RWQCB 2000).

Based on the assignment of a remedial category to each of the samples, Thiessen polygons were combined into larger remedial units (no action, MNR, or capping) as shown in Figure 1.

AWA concentrations were then calculated for the remedial units and compared to the Proposed RALs. The Proposed RAL based on an AWA concentration of 386 µg/kg was used for PCBs, and the Proposed RALs of 218 mg/kg and 410 mg/kg, respectively, were used for lead and zinc.

3. SEDCAM Evaluation

As shown on Figure 2, a variety of processes occur during MNR, including deposition of clean sediment, mixing and burial of surface sediment, and biochemical degradation. The SEDCAM model, which is accepted and used by Ecology (1991), is a one-dimensional mixing model that evaluates source loading, sediment deposition, chemical-specific degradation rate, and mixing. SEDCAM has been used in evaluating the potential success of MNR in the Portland Harbor Superfund Site (Anchor, 2005) and Commencement Bay Superfund Site (Jacobs et. al., 1988) and a modified version of SEDCAM was used in evaluating the likelihood of recontamination from Combined Sewer Overflow (CSO) events at the Norfolk Site in the Duwamish River (PNNL, 1995).

At Yosemite Slough, there are a variety of sources of cleaner sediment to deposit on the existing sediment surface during MNR: the areas identified for capping in the multi-technology alternative, the newly-constructed wetlands along the edges of the Slough, San Francisco Bay, post-remediation material from South Basin, and sedimentation from stormwater discharges. For this evaluation, readily available data for the Slough was used, which is limited to data for historical stormwater discharges. This also results in a more conservative estimation of the time required to reduce surface sediment concentrations to below RALs, as it does not account for the additional sources of cleaner sediment listed above.

3.1 SEDCAM Model

The SEDCAM model factors the initial contaminant concentration in sediment, the rate and total accumulation of sediments deposited in the mixing layer, and the concentrations of contaminants in the deposited sediment to calculate the concentration of the contaminants in surface sediment over time.

The SEDCAM model is as follows (Jacobs et al. 1988, Ecology 1991):

$$C(t) = \frac{M}{(M + kS)} C_p \left[1 - e^{\frac{-(kS+M)t}{S}} \right] + C_o e^{\frac{-(kS+M)t}{S}}$$

Where:

C(t)	=	mass in sediment at time t (milligrams [mg] or micrograms [µg])
M	=	sedimentation rate (grams per square centimeter per year [g/cm^2-yr])
k	=	combined first order rate constant for contaminant loss through decay and diffusion processes (yr^{-1})
Cp	=	mass in particles being deposited on the sediment (mg or µg)
t	=	time (yr)
Co	=	initial mass in native sediment (mg or µg)

The total accumulation of sediment in the mixed layer (S) is calculated as follows:

$$S = MLd(1 - p)$$

Where:

ML	=	thickness of mixed layer (cm)
d	=	density of sediment (grams per cubic centimeter [g/cm^3])
p	=	porosity of sediment (cm^3/cm^3)

The mass results of the SEDCAM model were then converted to concentrations by dividing the estimated mass of COC in the sediment by the mass of surface sediment particles in the area targeted for remediation, allowing for comparison of the SEDCAM results at time t to RALs. The concentration was calculated as follows:

$$C_t = \frac{C(t)}{MLdA}$$

Where:

C_t	=	concentration in sediment at time t (mg/kg)
C(t)	=	mass in sediment at time t (mg)
ML	=	thickness of mixed layer (m)
d	=	density of sediment (kg/m^3)

A = surface area (square meters [m^2])

3.2 Stormwater Loading

Stormwater discharges to the site from three nearby combined sewer overflow (CSO) outfalls shown on Figure 2: Griffith Outfall (OF-40), Yosemite Outfall (OF-41), and Fitch Outfall (OF-42). Stormwater analytical data were collected during the 2009-2010 rainy season by the San Francisco Public Utilities Commission (SFPUC). During that time, two overflow events were recorded discharging approximately 1.8 million gallons and 1.3 million gallons, respectively, from the three outfalls. Analytical data from the sampling events were provided in a September 26, 2011 letter (Herrera and O'Neil 2011).

Samples were collected by SFPUC from up to six locations during the two overflow events. However, metals data, including lead and zinc, were only analyzed from three samples representing the Griffith (OF-40) and Yosemite (OF-41) Outfalls. Metals data representative of the Fitch Outfall (OF-42) discharge were not available. PCB Aroclor data representing all three outfalls were available, and all results were non-detect. Aroclors were summed using half of the detection limit.

Average concentrations of lead, zinc, and PCBs from all of the outfalls from the two overflow events were applied to the recorded discharge to calculate the total potential contaminant mass load in milligrams. Calculated stormwater loading is presented on Table 2.

3.3 Model Inputs and Assumptions

It was assumed that 100 percent of the stormwater loading adsorbs onto particles and is deposited in the sediment at the site. This approach adds conservatism to the mass loading estimate because actual stormwater mass loading may deposit over a broader area further downstream than the site sediments, which would result in a lower sediment concentration within the site.

- Co – The initial mass in the sediment was based on the post-remediation AWA concentrations (see Table 1).

- Cp – The mass in particles being deposited on the sediment was based on the stormwater loading calculation results (see Table 2).

- M – A sedimentation rate of 1 cm/yr was assumed. This assumption was based on data available from the May 2, 2005 Hunters Point Shipyard Parcel F Validation Study Report, which estimates approximately 6 to 8 cm/yr of accumulation based on radioisotope data from two locations within the Slough (Battelle et al. 2005, Appendix M); and the September 2005 Hydrodynamic Modeling, Wave Analysis and Sedimentation Evaluation for the Yosemite Canal Wetland Restoration Project Report, which shows zero cm/yr of accumulation (Noble Consultants 2005). A rate of 1 cm/yr is considered to be a conservative estimate given the variable nature of the sedimentation data available.

- Surface Area – The surface area of the site is approximately 10.4 acres.

- ML – The mixed layer was assumed to be 15 cm across the site, which is consistent with the San Francisco Bay bioturbation depth.

- d and p – To calculate the total accumulation of sediments in the mixed layer, typical values for density and porosity of the sediment were evaluated. A density of 1 g/cm^3 and porosity of 0.64 cm^3/cm^3 were assumed based on the sediment classification made at the site during the geotechnical investigations.

- t – The COC sediment concentrations were calculated for a 5-year period. This period was assumed to be appropriate to predict potential concentrations that might be observed during a standard USEPA post-remedy 5-year review.

- k – The degradation rate (0.003 yr^{-1}) was estimated based on the mean degradation rate for Total PCBs from the literature (Lake et al. 1991; Beurskens and Stortelder 1995; Hollifield et al. 1995; Fish 1997; Van Dort et al. 1997). No degradation rate was used for metals.

3.4 SEDCAM Results

The stormwater loading calculation was estimated as mass per time (i.e., kilograms per year [kg/yr]). The resulting annual mass load was used in the SEDCAM model. The results of the SEDCAM model were then converted to concentrations by dividing the estimated mass of COC in the sediment by the mass of surface sediment particles in the area targeted for remediation. This was done by using the surface area of the remediation area, the depth of sediment in the model interval (i.e., mixing layer), and the density of the sediment.

The results of the SEDCAM analysis are summarized in Table 3. The modeled sediment concentrations were compared to the Proposed RALs. The modeled concentration resulting from loading from the three nearby CSO outfalls are:

- 0.318 mg/kg PCBs (82.3% of RAL[1])
- 104 mg/kg lead (48.1% of RAL)
- 112 mg/kg zinc (27.4% of RAL)

---

[1] The draft proposed action level for PCBs used in this evaluation is an AWA concentration of PCBs of 386 µg/kg, which corresponds to the calculated AWA for the post-remedial conditions at Hunters Point Parcel F (ARCADIS 2012).

4. Model Input Considerations

The following factors should be considered when reviewing the conclusions of the model.

4.1 Incoming Stormwater Mass

Incoming stormwater mass, while variable, is less than the AWA mass. Therefore, surface concentrations are predicted to stay below RALs in capped and no action areas. If the quality of stormwater changes significantly over time, this result could change.

4.2 Available Stormwater PCB Data

AWA concentrations and RALs were determined based on PCB congeners while the incoming PCB mass was calculated from available PCB Aroclor stormwater data. Congeners typically have a lower detection limit, and more congeners are used in the total PCB calculation (28 congeners) than the number of Aroclors (7). More detections and more compounds in the total PCB calculation could result in a higher incoming PCB mass.

4.3 Sedimentation Rate

Documentation of the sedimentation rate within the Slough is variable, and ranges from zero to 8 cm/year. A conservative estimate of 1 cm/year was assumed for the model input. Figures 4 through 6 provide the results of a sensitivity analysis conducted on the SEDCAM model. These graphs show the way that the surface sediment concentration reductions vary based on varying sedimentation rates. For reference, the proposed RALs are provided on each graph. Sedimentation rates less than 1 cm/year could result in a longer time period before reduction of surface sediment concentrations below the RALs, and sedimentation rates greater than 1 cm/year could result in reaching the RALs more quickly. Monitoring is a critical element of an MNR program, and monitoring results will provide direct measurements of the speed at which natural recovery processes are proceeding.

5. Conclusions

- Surface area weighted concentrations for COCs can be reduced to at or below the Proposed RALs in less than 5 years with a remedial alternative that includes areas of MNR along with areas of removal and capping.

- Employing MNR as a remediation tool reduces ecological and human health risk and eliminates disruption of the benthic community during implementation.

- Remedial alternatives that include MNR require less material handling and disturbance of the site and the surrounding areas and the public, as well as greater cost efficiency than more removal-intensive alternatives.

- Evaluating a remedial alternative that includes MNR is consistent with USEPA guidance to consider alternatives in order from least intrusive to most intrusive.

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Tables

Table 1
Post-Remediation Surface Area-Weighted Average Concentrations

Monitored Natural Recovery Evaluation Report
Yosemite Slough Sediment Site
San Francisco, California

AREA ID	Strategy	Unit Area (sqft)	AWAs PCBs (µg/kg)	Lead (mg/kg)	Zinc (mg/kg)
UNIT 1	MNR	8,329.7	135.8	268.3	405.7
UNIT 2	NO ACTION	16,302.0	45.0	31.6	56.5
UNIT 3	NO ACTION	36,532.4	677.0	176.3	247.3
UNIT 4	MNR	18,725.2	3,884.4	887.8	393.6
UNIT 5	CAP	62,471.0	26.4	43.2	158.0
UNIT 6	MNR	15,289.1	1,500.0	1,130.0	806.0
UNIT 7	NO ACTION	39,942.6	230.5	183.6	269.4
UNIT 8	MNR	13,733.0	960.0	267.0	312.0
UNIT 9	CAP	12,404.6	26.4	43.2	158.0
UNIT 10	MNR	36,020.9	1,742.1	267.4	372.5
UNIT 11	MNR	25,391.6	405.4	233.8	330.3
UNIT 12	NO ACTION	78,351.9	449.8	147.8	216.1
UNIT 13	MNR	36,326.0	1,535.8	756.9	468.3
UNIT 14	MNR	16,311.5	1,700.0	164.0	250.0
UNIT 15	NO ACTION	37,190.4	820.0	141.0	234.0
Total		453,321.9	813.9	264.5	283.3

AWA = area-weighted average
MNR = monitored natural recovery
sq ft = square feet
µg/kg = microgram per kilogram
mg/kg = milligram per kilogram

Table 2
Calculated Stormwater Loading

Monitored Natural Recovery Evaluation Report
Yosemite Slough Sediment Site
San Francisco, California

	Total Event Discharge (gallons)	Total PCB Concentration (mg/L)	Lead Concentration (mg/L)	Zinc Concentration (mg/L)	Total PCB Load (mg)	Lead Load (mg)	Zinc Load (mg)
Storm Event 1	1,800,000	0.000147	0.0110	0.106	1,004	74,713	719,736
Storm Event 2	1,300,000	0.000263	0.000671	0.0127	1,294	3,301	62,313
Total (mg/yr)	3,100,000	--	--	--	2,299	78,014	782,048

mg/L = milligrams per liter

Table 3

Modeled Sediment Concentrations Compared to Remedial Action Levels

Yosemite Slough Sediment Site
San Francisco, California

COC	SEDCAM Predicted Concentration	Proposed AWA Remedial Action Level[1]	SEDCAM Percentage of Remedial Action Level
Total PCBs (mg/kg)	0.318	0.386	82.34%
Lead (mg/kg)	104.780	218	48.06%
Zinc (mg/kg)	112.31	410	27.39%

Notes:

1. The draft proposed action level, as an AWA concentration of PCBs, is 386 µg/kg, which corresponds to the calculated AWA for the post-remedial conditions at Hunters Point Parcel F (ARCADIS 2012).

mg/kg = milligrams per kilogram
AWA = area-weighted average
COC = contaminant of concern

Figures

CITY: SF DIV/GROUP: ENV/IM DB: KERNST LD: PIC: PM: TM: TR:
PROJECT: (PROJECT #)
PATH: Q:\Shell\YosemiteCreek\RemedialAlternatives\AWA_Calcs\MXD\EE-CA_RemedialAlternative_Including_MNR.mxd 7/18/2012 2:39:11 PM

	Remedial Action Level	Area Weighted Remedial Action Level	SAWC @ T = 5 Years
Total PCBs	1,240 µg/kg[3]	386 µg/kg	314 µg/kg
Lead	218 mg/kg	--	105 mg/kg
Zinc	410 mg/kg	--	112 mg/kg

SAMPLE LOCATION WITH RESULTS
BATTELLE SAMPLE LOCATIONS
PROPOSED REMEDIAL ACTION AREA BOUNDARIES
REMOVE AND CAP
MNR
NO ACTION
SITE BOUNDARY

SAMPLES COLLECTED AS PART OF THE HUNTERS POINT SOUTH BASIN FEASIBILITY STUDY
APPROXIMATE RESTORATION AREA BOUNDARIES
PHASE I RESTORATION AREA (COMPLETED 2011)
POTENTIALLY SUBMERGED PORTION OF PHASE I WETLAND RESTORATION AREA
PHASE II RESTORATION AREA (SCHEDULED FOR 2013)
WETLAND RESTORATION ISLAND

YOSEMITE SLOUGH SEDIMENT SITE
SAN FRANCISCO, CALIFORNIA

ALTERNATIVE 1:
MULTI-TECHNOLOGY ALTERNATIVE

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FIGURE
1

Notes:
1. Sediment data shown on the figure represent the measured concentration at each sample location from 0 ft to 1 ft bss.
2. The PCB TMDL for San Francisco Bay assumes a biologically active sediment layer of 15 cm (approximately 6 inches).
3. Hunters Point has a Cleanup AWA Goal of 386 µg/kg
4. Chemistry Results Samples collected for the Hunters Point South Basin Feasibility Study were excluded from area weighted concentration calculations.

07/18/2012 SYRACUSE, NY-ENV/CAD-DJHOWES
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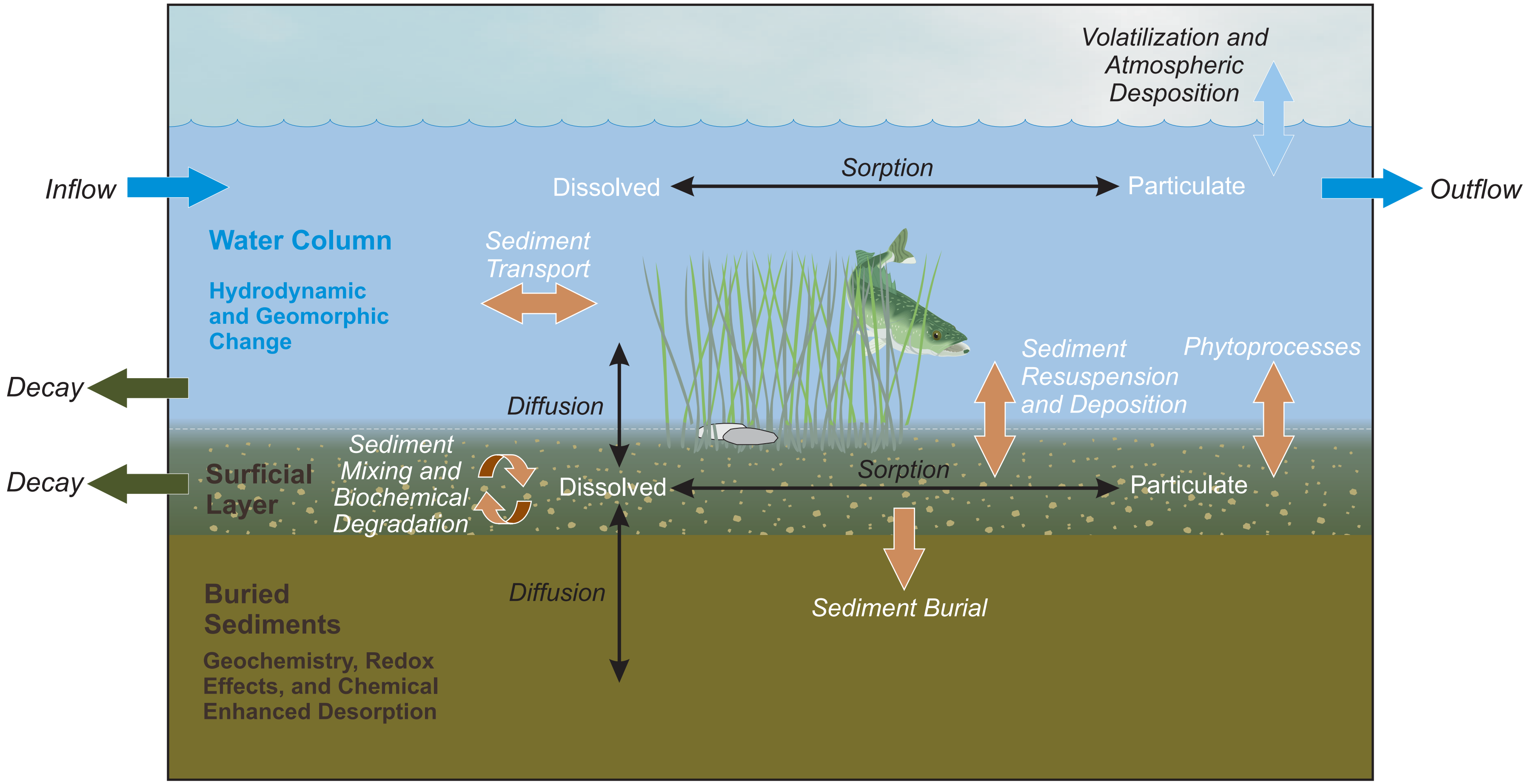

DRAFT

YOSEMITE SLOUGH SEDIMENT SITE
SAN FRANCISCO, CALIFORNIA

CONCEPTUAL DEPICTION OF MNR PROCESSES

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FIGURE
2

Legend

Approximate Outfall Location

Site Boundary

0 250 500

SCALE IN FEET

YOSEMITE SLOUGH SEDIMENT SITE
SAN FRANCISCO, CALIFORNIA

CSO OUTFALLS DISCHARGING TO YOSEMITE SLOUGH

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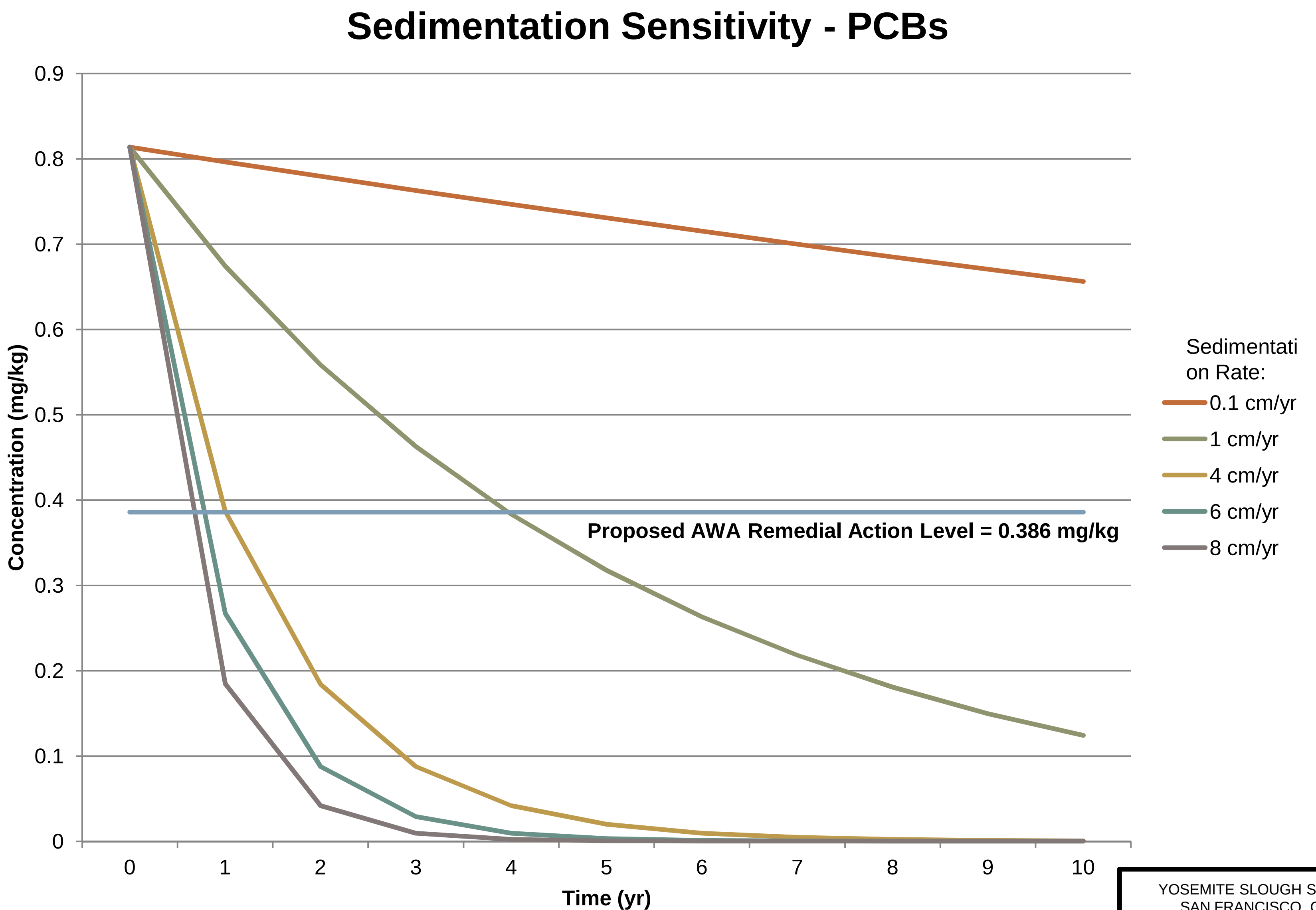
FIGURE 3



YOSEMITE SLOUGH SEDIMENT SITE
SAN FRANCISCO, CALIFORNIA

PCB SENSITIVITY ANALYSIS

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FIGURE
4

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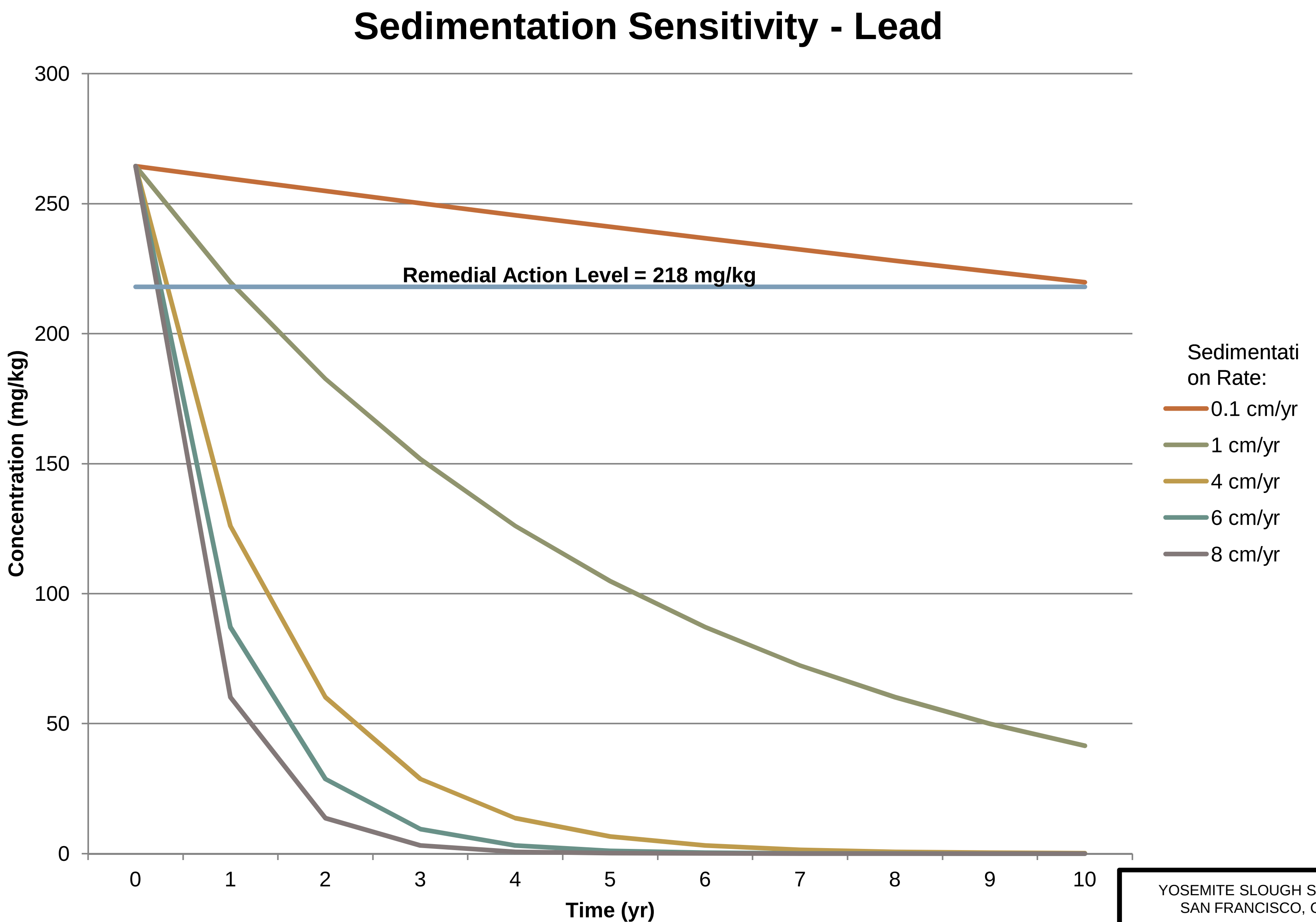

YOSEMITE SLOUGH SEDIMENT SITE
SAN FRANCISCO, CALIFORNIA

LEAD SENSITIVITY ANALYSIS

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FIGURE
5

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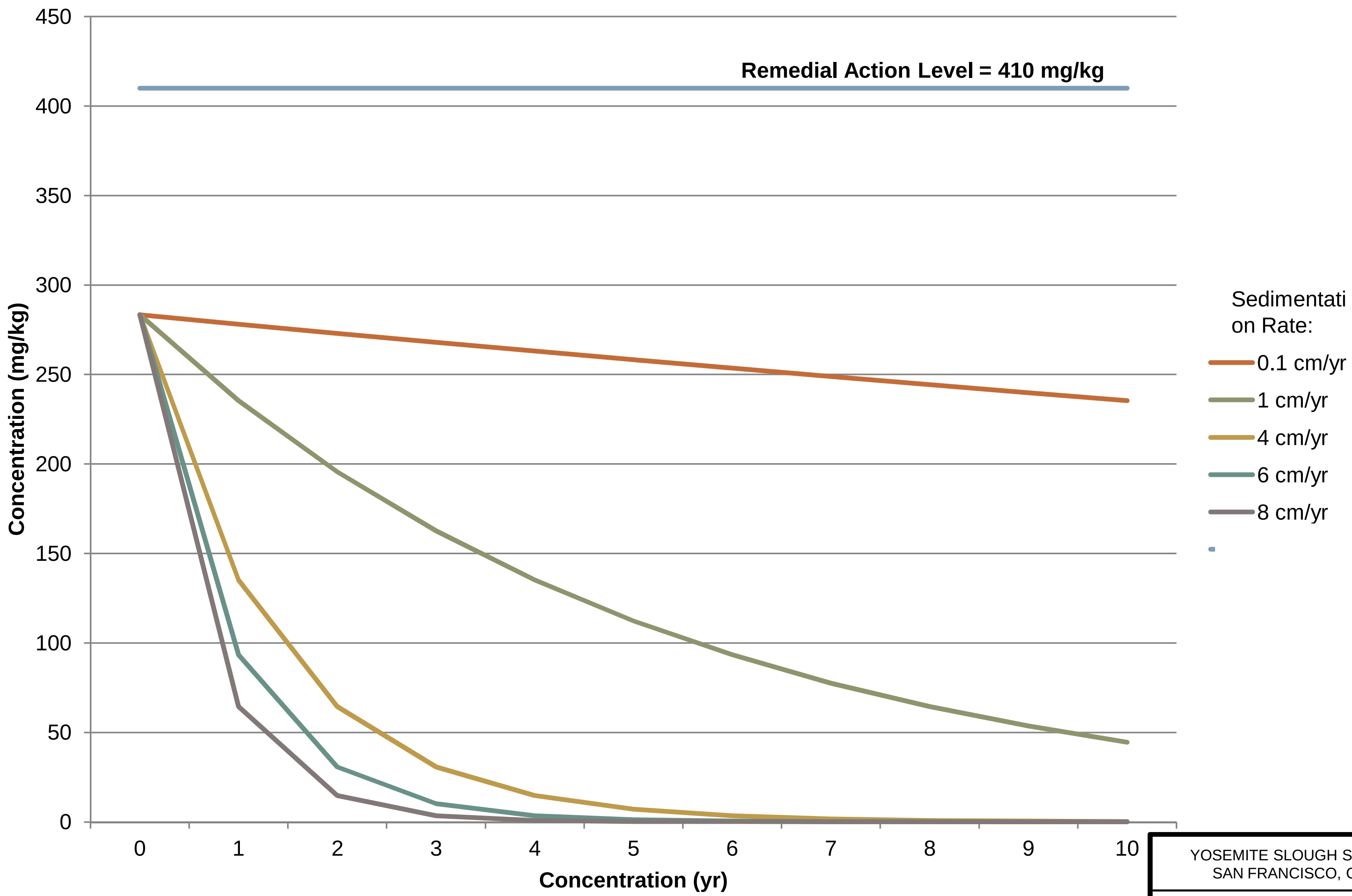
Sedimentation Sensitivity - Zinc



YOSEMITE SLOUGH SEDIMENT SITE
SAN FRANCISCO, CALIFORNIA

ZINC SENSITIVITY ANALYSIS

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FIGURE
6

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